# Newton's 1st Law & Resulting Motion Lab 5: Relative Speed

## Introduction

In this lab, students will explore how motion is relative to how an observer sees it. This is to say that certain objects can seem to be moving faster or slower based on how you see them moving. Does a car seem to be moving faster when it moves towards you or when it moves to you from behind? When looking our a window of a car, do the trees move towards the car or does it just seem this way because the person viewing the trees are moving?

**Question / Aim:** Experimentally measure the relative speeds of two objects moving in the same and in the opposite directions.
**Independent Variable:** Motion of objects relative to one another.
**Dependent Variable:** Relative speed.
**Controlled Variable(s):** Object's speed.

Hypothesis
The motion of a car is consistent wether you observe the car from a stationary point or not.

The motion of a car changes if you observe the car while moving.

## Design

### Supply List

Constant velocity cars, C batteries, metal rod, stopwatches, meter sticks, masking tape.

### Procedure

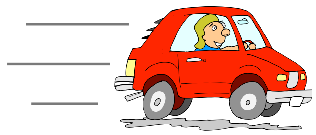
1. Determine the average velocity in m/s of each of the two vehicles you are using in this lab. Explain what you did to determine the average speeds. Draw a picture of your setup, and explain in words the process you followed.

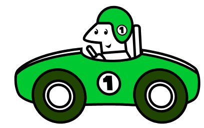
Blue Vehicle ______ : __________ m/s

Red Vehicle ______ : __________ m/s

# One Car Moving

Now that you know how fast your cars will travel, determine how fast the red car will appear to be moving towards the blue if only the red car is moving. To do this, imagine you are an observer seated in the blue car and you are observing the motion of the red car.





Place the two cars facing each other 2.00 m apart. Turn on the red car and release. Measure the amount of time it takes for the two vehicles to meet. Use two timers and perform two trials.

| Distance Apart (m) | Time to Meet (s) | | | | Average Time (s) | Measured Relative Speed (m/s) |
|---|---|---|---|---|---|---|
| | Trial 1 | | Trial 2 | | | |
| | Timer 1 | Timer 2 | Timer 1 | Timer 2 | | |
| **2.00** | | | | | | |

1. Average the four time values together and record in the data table. Divide the distance traveled by the car to find the speed. This is considered relative speed. Show work to find speed.

Whenever you measure speed, you have to "stand somewhere" to make the measurements. In other words, you must consider some object (the one you are standing on, probably) to be at rest, and measure the speed of other objects *relative to it* - that is, as if it were at rest.

When we measure speeds, we commonly stand on the Earth (or something attached to the Earth) to make the measurements. A physicist would say that the speed is measured *relative to the Earth* or in the *Earth frame of reference*. Notice that it is quite useful and consistent to treat the Earth as if it were at rest - even though we know that it really isn't at rest at all! In the previous test, you imagined that you were sitting in the blue car which was at rest. Therefore this is an example of measuring speed in the Earth frame of reference.

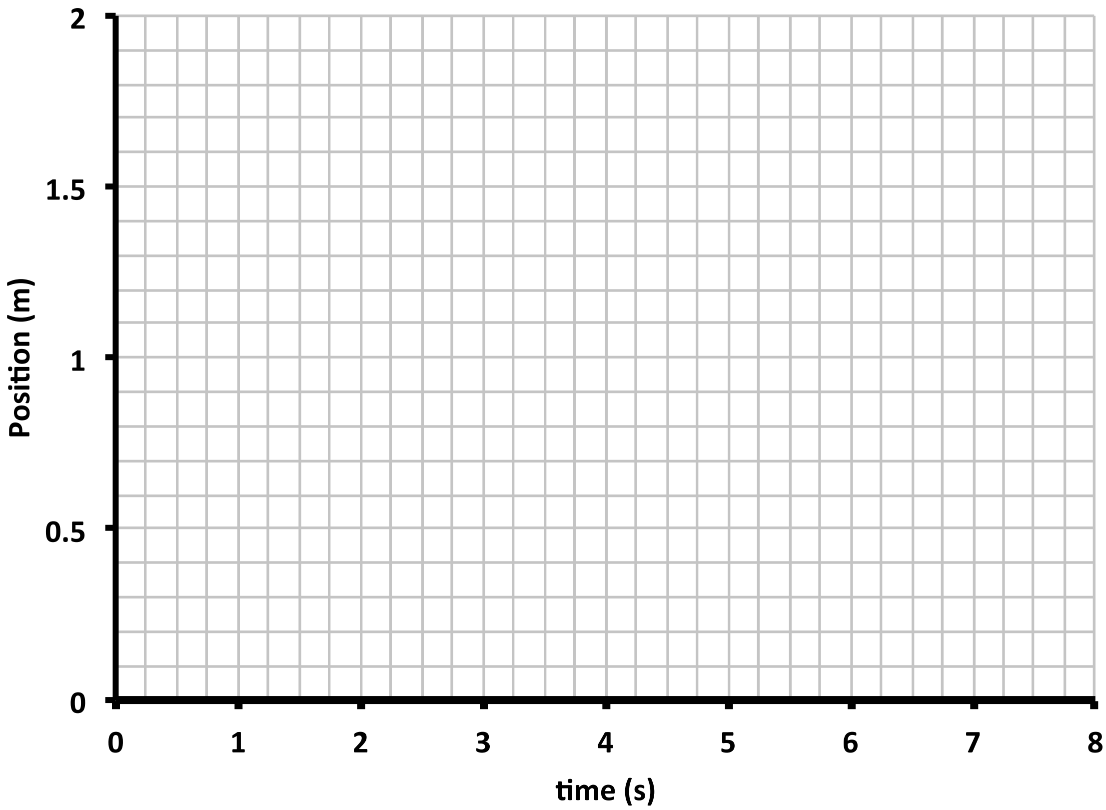
Isaac Newton, among other prominent physicists, believed that even the speeds that we commonly calculate are relative quantities. This means that the speed measured will be dependent upon the frame of reference that you observe the motion.

2. If we repeated this process but allowed the red car to start further away, would you calculate a different speed? Why or why not.

3. If we repeated this process but had the red car moving away from the blue car, would you calculate a different speed? Why or why not.

Create a position vs. time graph for the motion of the two cars starting 2.00 m apart. Use the speeds found in procedure step 1. Imagine that the red car's starting position is the origin. Use a different colored pencil to depict the different cars.

# Graph 1

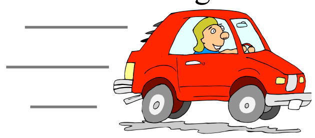


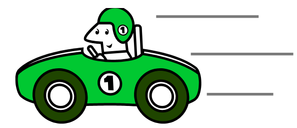

Using a third color pencil, draw a vertical line between the lines that represent the two cars. Draw a line for each second.

The length of the line represents the distance that the two cars are apart. Notice that as time goes on the line is getting shorter. It should be getting shorter by an amount equal to that of the speed of the moving car.

# Moving Opposite Directions – Toward Each Other

Now lets see if allowing the blue car to move changes the speed calculation of the red car.





4. Based on the average speeds that you determined for your two vehicles, what do you predict the calculated speed to be of the red car as they approach each other from opposite directions? (i.e., At what rate will it appear that the red car is driving towards the blue car?) _______ m/s. Describe why you made this prediction.

Place the two cars facing each other 2.00 m apart. Turn on both cars and release at the same time. Measure the amount of time it takes for the two vehicles to meet. Use two timers and perform two trials.

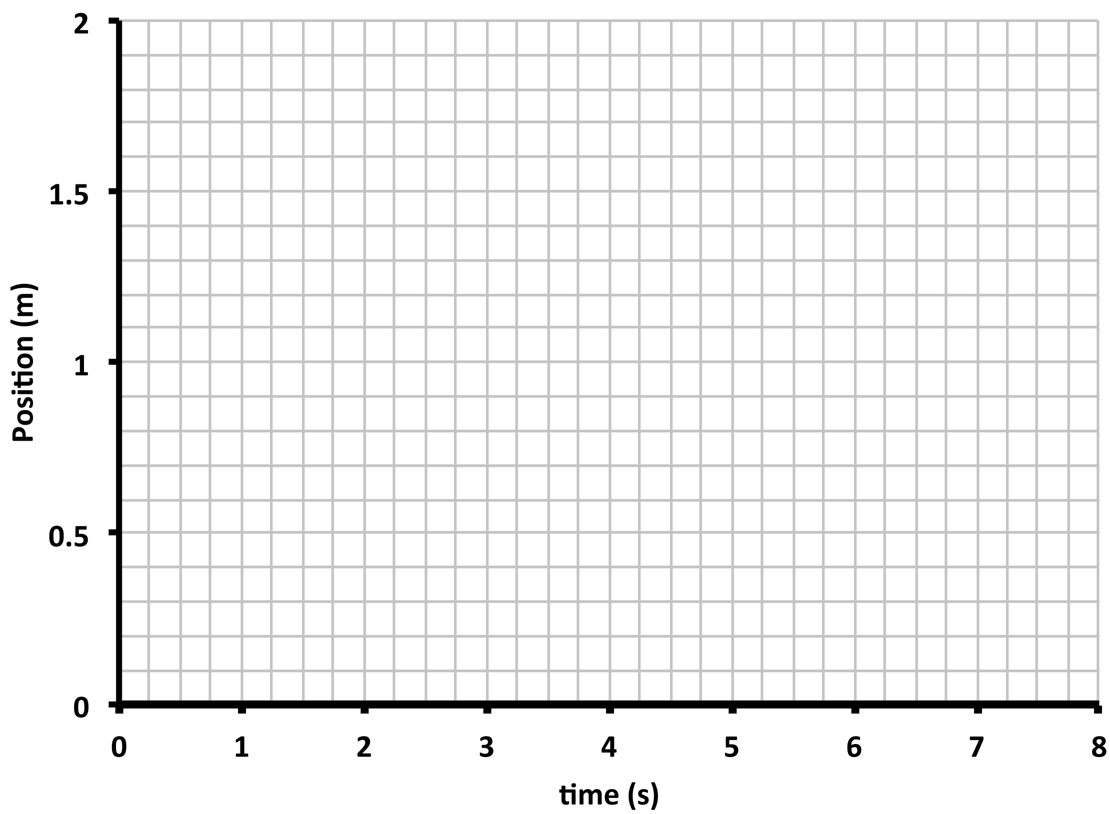
Average the four time values together and record in the data table.

Divide the distance apart by the average time to meet in order to calculate the relative speed (s= d/t).

| Distance Apart (m) | Predicted Relative Speed (m/s) | Time to Meet (s) | | | | Average Time (s) | Measured Relative Speed (m/s) |
|---|---|---|---|---|---|---|---|
| | | Trial 1 | | Trial 2 | | | |
| | | Timer 1 | Timer 2 | Timer 1 | Timer 2 | | |
| 2.00 | | | | | | | |

Create a position vs. time graph for the motion of the two cars starting 2.00 m apart. Imagine that the red car's starting position is the origin. Use the speeds found in procedure step 1. Use a different colored pencil to depict the different cars. Your red car should have a positive slope, and your blue car should have a negative slope because it it going in a different direction.

## Graph 2



Notice that your graph now looks different than the first graph your created. Now the cars meet at a time much sooner than when only one car was moving.

Using a third color pencil, draw a vertical line between the lines that represent the two cars. Draw a line for each second.

1. How does the rate at which the line gets smaller compare from graph 1 to graph 2?

2. What does this mean in terms of the distance between the cars in graph 2 compared to graph 1?

3. This this because the red car is now moving faster? How do you know based on the two graphs?

Because speed is relative, the measurement of speed depends on if you measure it from a stationary frame of reference or a moving frame of reference. If you were standing on the side of the road and looking at the trees along that road you would say that the speed of the trees is 0.00 mph because they are not moving. However, if you are driving down the road at 60 mph, and look at the trees along the road, it appears that the trees are moving towards you. The trees would appear to be moving towards you at 60 mph.

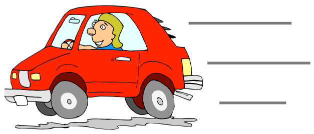
4. If you are driving the blue car, does it seem like the red car is moving towards you faster or slower than it did in the first trial?

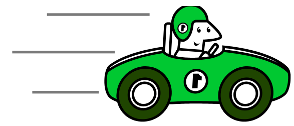
5. Is this because it actually is? Explain.

Because both the cars are moving towards one another, to find their relative speeds we simply add their speeds together. Finish the following equation:

$$S_{relative} = S_{red} + \underline{\hspace{3cm}}$$

What if the cars were moving away from each other as seen below. Run a trial but do not time, simply observe.





5. Does the distance between the cars increase faster, slower, or at the same rate as when only one car is moving?

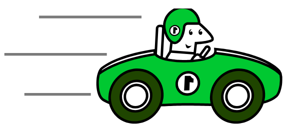
6. If this is true, then does the red car move away from the blue car faster or slower than if the blue car was sitting still? Explain why.

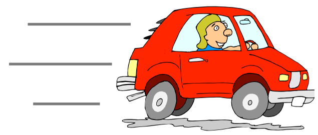
7. Does this mean that the relative speed of the car is faster or slower than its actual speed?

8. Write the equation that shows the relative speed of the red car in compared to the blue car.

# Moving Same Direction – Faster Car in Front:

Determining their relative speed when the cars are traveling in the same direction and the faster car is in front pulls away from the slower rear car.





9. Based on the average speeds that you determined for your two vehicles, what do you predict the calculated speed to be of the red car as they pull away from the blue car? (i.e., At what rate will it appear that the red car is driving away from the blue car?) _______ m/s. Describe why you made this prediction.

Begin each run with the fronts of the cars 50 cm apart.

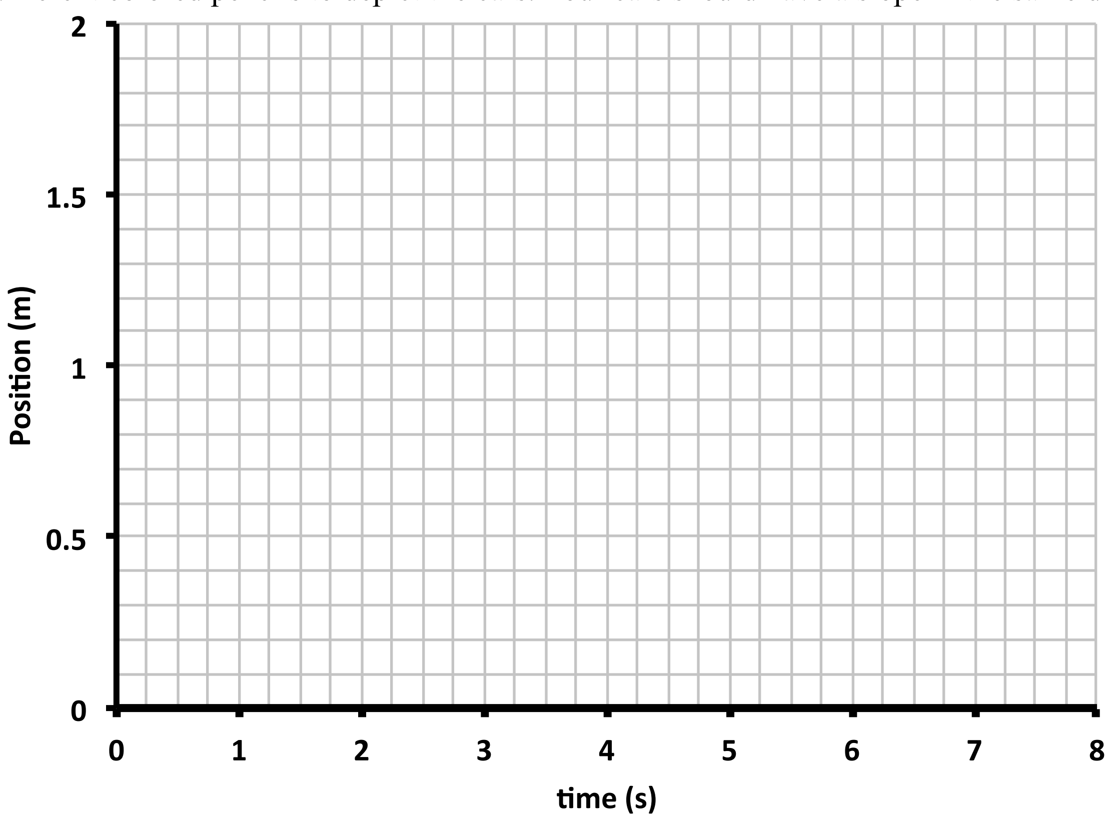
Place the two cars facing the same direction at their starting positions. Release the cars at the same time and have spotters note the positions of the fronts of the cars 4 seconds after release. Measure their new distance apart and record in the data table. Perform another trial and record in the data table.

Subtract the initial distance apart from the final distance apart to obtain the change in distance apart. Divide the average change in distance apart by the time to determine their relative speed.

| Initial Distance Apart (m) | Predicted Relative Speed (m/s) | Running Time (s) | Final Distance Apart (m) | | Average Distance Apart (m) | Change in Distance Apart (m) | Measured Relative Speed (m/s) |
|---|---|---|---|---|---|---|---|
| | | | Trial 1 | Trial 2 | | | |
| **0.50** | | **4** | | | | | |

Create a position vs. time graph for the motion of the two cars. Imagine that the blue car's starting position is the origin. Use a different colored pencils to depict the cars. Your cars should have a slope in the same direction.

## Graph 3



Using a third color pencil, draw a vertical line between the lines that represent the two cars. Draw a line for each second.

Remember that the vertical line represents the distance between the two cars. Because the cars are getting further apart the vertical line is getting longer.

6. If the blue car was not moving, would the vertical line get longer faster or slower than what happens in graph 3?

The distance that the red car moves away from the blue is less each second because the blue car is moving in the same direction. Because of this, the speed of the red car seems less than if the blue car was not moving.

7. Does this mean the red car is now moving slower? How do you know based on your three graphs?

Because both the cars are moving in the same direction, to find their relative speeds we simply subtract their speeds. Finish the following equation:

$$S_{relative} = S_{red} - \underline{\qquad\qquad}$$